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PEACETIME INNOVATION AND THE US ARMY CORPS OF ENGINEERS:
MANAGING TECHNOLOGY FOR INDUSTRIAL APPLICATION

A Monograph
by
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School of Advanced Military Studies
United States Army Command and General Staff College
Fort Leavenworth, Kansas

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MONOGRAPH

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TECHNOLOGY	CORPS OF ENGINEERS	INDUSTRY	79
HAZARDOUS WASTE	RISK MITIGATION	BASE CLOSURE	
INNOVATION	REMEDIATION	LIABILITY	

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MONOGRAPH APPROVAL PAGE

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ABSTRACT

PEACETIME INNOVATION AND THE US ARMY CORPS OF ENGINEERS: MANAGING TECHNOLOGY FOR INDUSTRIAL APPLICATION
by Major Alex C. Dornstauder, USA, 79 pages.

This monograph introduces potential strategic roles for the US Army Corps of Engineers in the development of technology for industrial applications. Specifically, the market for remediation of hazardous wastes at sites in the United States, both military and private, is explored. The *innovation environment*, that is, the quantity and lethality of hazardous wastes at military sites is introduced to highlight its efficacy in developing high risk, high payoff remediation technologies. A number of remediation technologies are also introduced along with their relative progress towards industrial application. The primary conclusion is that the US Army Corps of Engineers can effectively and more efficiently bring new remediation technologies to private industry than private industry itself. This would be done by using the corps' organic construction management assets at contaminated military sites in a *test bed* or *incubator* fashion to hedge high market risk and post-project liability.

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I. INTRODUCTION

> Peacetime . . . innovation, is concerned with social innovation, with changing the way men and women in organizations behave . . . It introduces a new set of domestic actors, scientists, into the community within which military decisions are made. In short, technological innovation gives rise to an additional set of questions beyond those associated with organizational innovation.[1]

The purpose of this monograph is to investigate the feasibility of employing the US Army Corps of Engineers to foster peacetime technological innovation for hazardous waste remediation. Specifically, employing the Corps in a government-industry team for the public-private transfer of technology for industrial application. To this end, this monograph is couched in the proposition that our nation has no viable technology strategy, or policy, where both government and industry work in harmony toward a specific end.[2] The argument will be presented by 1) describing the problem of inhibited technological innovation in hazardous waste remediation; 2) identifying a potential role for the US Army Corps of Engineers the government's construction agent; and 3) proposing a value-added scheme for the US Army Corps of as a strategic player in this market. The topics of technological innovation and hazardous waste remediation remain both timely and germane to the United States Armed Forces and suggest a potential crossover from a peacetime to a wartime, tactical environment. As DoD scales down

operations, base closure and cleanup of hazardous wastes have become crucial issues[3]. Remediation of contaminants at these sites must be accomplished in a timely and cost effective manner. Private construction industry experience in this area indicates the need for new and improved cleanup technologies[4]. However, the specters of future liability and litigation have seriously hindered efforts toward this end.[5] Employing the US Army Corps of Engineers in a strategic role of managing technological innovation here will help to solve this national dilemma.

PROBLEM STATEMENT

Stephen Peter Rosen, in his book **Winning the Next War: *Innovation and the Modern Military***, commented on the study of technological innovation in the nonmilitary world:

> The study of technological innovation in the government and business world . . . . has not proceeded so far as to provide any clear - cut models for the study of technological innovation in the military.[6]

This is a significant proposition, for it asserts that the dogmatic emphasis and romance the United States Armed Forces places on developing and using the latest technologies is proceeding randomly, emotionally and, consequently, less than optimally. If our military is to be the standard bearer of technological superiority, then we must understand the underlying mechanisms and subtle forces which drive, and

inhibit, its achievement. An understanding of peacetime technological innovation is a step in the right direction. Determining whether the US Army Corps of Engineers can be the agent of change in such a model would be an even greater step towards understanding the roles and missions necessary for defining innovative success.

RESEARCH QUESTION

Can the US Army Corps of Engineers foster peacetime technological innovation for transfer to the private hazardous waste remediation industry? The word *foster* (to cause to progress or proceed towards a goal) is used intentionally to highlight the fielding of new technologies specifically for private sector application. It is used so as not to imply the Corps is developing new technologies, or methods for implementing them, on its own. Related questions include: *Why the Corps, and not other agencies or industries, should take the lead in developing these technologies? How can the Corps play an important role in this area? Should they? Why do firms innovate? Why not?* and *If innovation is necessary, can the Corps accelerate it?* The issues of efficiency, that is, can the Corps do better (with a greater benefit-to-cost ratio) than other public agencies or private concerns, though critical to developing

an Army technology strategy, are beyond the scope of this monograph.

HYPOTHESIS

The US Army Corps of Engineers is uniquely capable to lead peacetime technological innovation for the private hazardous waste remediation industry. ***If* the US Army Corps of Engineers assumes the role of "test bed" or "incubator" at military hazardous waste sites, *then* innovative remediation technologies will be developed and privatized more quickly and cost effectively.**

As the *Nation's Engineer*[7], the corps is capable of providing technically and scientifically feasible alternatives, but most importantly, with the management vehicle to see them through. It is a stable, government organization capable of bearing significant financial and operating risk.

This monograph is a call for employing the US Army Corps of Engineers to foster innovative hazardous waste remediation technologies and construction management programs. The central thought is that these technologies and critical management programs, once developed in a relatively low risk[8] environment at military installations, would be directly transferable to the private sector for

cleanup of Superfund and RCRA sites. As a result, our domestic technology base and pool of responsible construction contractors would be strengthened, bolstering our Nation's competitiveness in this burgeoning global industry.[9]

Remediation of hazardous chemical wastes sites is an inherently uncertain proposition. Private entrepreneurial investment in such an endeavor is at a considerable cost premium and requires substantial short-term return on investment. Exposure to potential litigation makes such ventures nearly impossible. Small contractors attempting to penetrate the market with innovative remediation processes cannot secure bid or performance bonding. Larger firms with proven technologies yet *deep pockets* cannot justify the risks with expected returns.[10] Without some sort of subsidy, the market tends to force new players from the scene, implicitly promoting more conservative technologies and remediation processes, ultimately encouraging overall inefficiency. As subsequent discussion will show, it is here the corps can serve as a *test bed* or *incubator* for technological innovation[11], leading to a more dynamic privatization of the remediation process. Using alternative procurement mechanisms, such as *design-build*[12] or other *turnkey*[13] approaches (both of which involve intense

government-contractor coordination and reduced contract duration), these market risks can be reduced. Pursuing traditional competitively bid contracts for innovative projects, the Corps could hold contractors liable only to the limits of the contract, not to the standards of processes yet to be developed. In this way, contractors are *de facto* indemnified if a new remediation technology is a loser with the Corps assuming the *ex post facto* responsibility. In this way, the technology itself is at risk, not the contractor. Such a method delivers the needed subsidy in the form of risk attenuation resulting in correspondingly lower costs of capital, bid bonding, and performance insurance for prospective contractors. Overall contract costs are lower with, in the case of alternative procurement mechanisms, constructability[14] and biddability[15] engineered directly into the design making the final product more technically and financially sound. Innovative technologies for hazardous waste remediation brought more quickly to the market, at a lower cost, provide more and better information for our national policy makers and scientists, increasing our nation's competitiveness abroad, ensuring a better hold on our commitment to the environment and national security.

ASSUMPTIONS

Underlying this hypothesis are the assumptions that 1) new and innovative remediation technologies are necessary for more complete and timely remediation of hazardous waste sites[16] and 2) that cleaning contaminated sites (both civilian and military) will continue to be a national priority and legislative mandate, especially under our future Democratic administration.[17] These two assumptions are based on present practices (EPA and the Corps) of prioritizing sites by level of contamination and assigning remediation urgency in a "worst first" fashion.[18] In other words, we are working from dirtiest site to cleanest site. In this way, we eliminate the greatest dangers first and attend to lesser threats as time and resources permit. Logically, as the number of available remediation technologies grows, the more effectively this policy will proceed. However, contamination is a dynamic problem and lesser threats become exacerbated if left unremedied. Consequently, alternative assignment strategies of remediation urgency are also of import.[19] It is here that the Corps can contribute most by managing the development of remediation technology innovation through DoD programs at contaminated military installations.

MONOGRAPH STRUCTURE

The next section of this monograph, **ENVIRONMENT OF INNOVATION**, addresses the background and significance of this problem by describing the risks and responsibilities associated with military hazardous waste remediation. The **REMEDIATION TECHNOLOGIES** section introduces the actual technologies for use at contaminated sites and describes where and when each is appropriate. Appendix C, STRATEGIC MARKET ANALYSIS, to this section is based upon Michael E. Porter's *Value-Added Chain* in **Competitive Advantage** (New York: The Free Press, 1985) and presents a strategic market analysis of the hazardous waste remediation industry to help evaluate potential roles for the Corps in peacetime technological innovation. The **CONCLUSIONS/IMPLICATIONS** section states specifically why the Corps should be employed to foster innovation concerning hazardous waste remediation technologies and thus potential crossover insights toward the application of innovation in the tactical realm. It synthesizes the preceding discussions and restates the central thought of the monograph, focusing specifically on our military environmental programs as a vehicle for the Corps in managing peacetime technological innovation and fostering private sector development. Appendix A presents definitions of commonly used terms. Appendix B is a

glossary of acronyms. Appendix D offers suggestions for further research in this most important and sensitive area.

II. ENVIRONMENT OF INNOVATION

> Because the service is a political community, innovation does not simply involve the transfer of resources from one group to another. It requires an 'ideological' struggle that redefines the values that legitimate the activities of the citizens . . . . [However], without the development of new critical tasks, 'ideological' innovations remain abstract and may not affect the way the organization actually behaves.[20]

RISK

With the possible exception of the former Soviet military, the United States armed forces is arguably the most indiscriminate and irresponsible polluters on earth. In the interests of national security, we deposit thousands of tons of hazardous materials into the environment each year, both on federally owned reservations and private property. Much about these wastes, and the problems they cause, is already known. However, discovery of contaminated "hot spots" is not by any measure complete.

MAGNITUDE OF THE PROBLEM

The Defense Department (DoD) is a major producer of hazardous waste. DoD generates over 400,000 tons each year from industrial processes, primarily used to repair and maintain weapons systems, such as F-16 Aircraft, and equipment (trucks). DoD data show that in 1986 the Air Force, the Army, and the Navy generated about 96,000, 139,000, and 183,000 tons, respectively, of hazardous waste.[21]

Virtually every major military installation in the US, as well as numerous minor facilities and former bases, has caused extensive environmental damage. And the extent of this toxic legacy continues to grow. DoD owns 3,874 properties in the US and its territories, including 871 major military installations. As of September 30, 1986, the DoD had identified 3,526 "potentially contaminated" sites at 529 locations. Six years later, the total now stands at over 17,000 sites at 1,579 locations.[22,23] Additionally, more than 1,200 public and private properties around the US are currently listed, or are proposed for listing on the EPA Superfund National Priorities List or *NPL*.[24] The Pentagon is a Potentially Responsible Party (PRP) at 53 of the privately owned NPL sites, including dumps, properties formerly owned by the military, and contractor owned weapons plants.[25]

The number of facilities identified as having contamination problems is expected to level off soon, since the armed forces have surveyed most of their facilities.[26] However, as the discovery of new sites continues to be a major task, this assertion may have little merit. Additionally, degradation of currently identified sites will continue to confound remediation, cleanup, and base closure efforts as long as quick and decisive actions are delayed

with procedural questions. Considering the size and complexity of the effort required for comprehensive remediation at these sites, managing technological innovation toward this end state is critical.

TYPE OF TOXICS

The military chemicals which permeate our environment include industrial solvents, paints and dyes, fuels and propellants, acids, pesticides, herbicides (containing dioxins), heavy metals, PCBs, photographic chemicals, refrigerants, asbestos, cyanide, and medical wastes ... nerve gas and unexploded artillery shells ... (and) combined radioactive and toxic wastes.[27]

The toxicity of most military hazardous wastes is not materially different from their civilian counterparts. In fact, there does not appear to be any evidence that the majority of military toxics pose a greater threat, chemically, than those found at private sites. It is secrecy and noncompliance with reporting requirements that cause dangers to human health and surrounding ecosystems when remediation efforts are confounded.[28]

Military specific wastes (chemical munitions and unexploded ordnance) do, however, pose special threats to the environment and public safety. The immediate danger of explosion or lethal release during removal and remediation

being the primary concerns. Further contamination through decomposition and leaching, much like heavy metals at industrial sites, is also a significant problem. This is especially true considering the size and number of active and abandoned training installations where indirect fire (artillery shells) have impacted and remain unexploded.

ENVIRONMENTAL IMPACT

As with contaminants at civilian sites, intercompartmental[29] migration (that is, between various media, such as between soil and groundwater) is a concern at DoD installations. Groundwater contamination and volatilization of toxics are only two of the many mechanisms which facilitate migration between these environmental compartments. Military toxics, though not significantly different with regard to their migratory nature, also contaminate surrounding ecosystems beyond the borders of DoD installations.

Migration pathways of contaminants do not recognize the sanctity of political boundaries nor the limits of military reservations. Not only are service members and their families at risk. Bordering communities and activities are also impacted when toxics contaminate drinking water supplies and the surrounding air. Considering the number and size of sites worldwide, that impact is substantial.

However, it is only now beginning to be addressed by Pentagon officials.[30]

Remedial inaction also exacerbates environmental problems at military hazardous wastes sites. Not unlike their civilian counterparts, military cleanup efforts are delayed for numerous reasons, *budgetary shortfalls* and *national security* the most noteworthy. These delays amplify the problems caused when contaminants migrate and spread by way of geologic and intercompartmental pathways to neighboring population centers. The environmental opportunity costs of delayed responses are significant and speak for a revised approach, focused on action and remediation.

RESPONSIBILITY

MILITARY ENVIRONMENTAL PROGRAMS

It is clear that our military's past environmental practices have been negligent and reckless. Yet current DoD waste management practices continue to jeopardize the environment.[31] Recognizing this, the Congress enacted the Defense Environmental Restoration Act in 1986 which mandated that DoD establish the *Defense Environmental Restoration Program (DERP)*. This is the DoD level response to contaminants generated by military commands and is the

authority from which all other military environmental response programs spring. Each of our services has since established their own environmental restoration programs. The following discussion will concentrate on those effected by the Department of the Army (DA).

The *Installation Restoration Program (IRP)* is the DA plan for cleanup of its contaminated sites. It is a comprehensive and innovative effort by which DA will meet the standards and requirements of the DERP. Included in this are contracting mechanisms, public participation requirements, and directions for interagency coordination agreements with EPA, and state and local governments. The plan is published by the US Army Toxic and Hazardous Materials Agency, an arm of the Corps of Engineers. Action responsibility for the success of the program is delegated to the installation engineer or DEH (Directorate of Engineering and Housing).[32]

The *Formerly Used Defense Sites (FUDS)* program is DA's equivalent to the Superfund. The purpose of this program is, as its name implies, to cleanup formerly used defense sites which are now either inactive or abandoned. Sites can be located on federal or private property with one or more responsible parties, that is, DoD and its contractors. The

US Army Corps of Engineers is the executive agency responsible for this program.

The *Integrated Hazardous Material/Hazardous Waste (HM/HW) Management Plan*, now in its formative stages, is a draft program by which DA will reduce its hazardous waste generation by 50%, compared to its 1984 levels, prior to the end of fiscal year 1992. This waste minimization effort, as mandated by the Congress in the 1986 Defense Environmental Restoration Act and DoD in the DERP, is an attempt to bind DA agencies together through standardized reporting and monitoring procedures. As an action plan, it assigns responsibilities and timetables for completion of critical actions to specific DA agencies and major commands.

ASSESSMENT OF THE PROGRAM

As an instance of programmatic innovation, the DERP's strength lies in its action orientation. It directs the United States Armed Forces to produce measurable results in helping to mitigate the impacts of day-to-day operations. This is not a significant departure from similar civilian programs. However, the organization within which action will be carried out is--DoD is results oriented and task organized. The military's default setting is "action instead of deliberation" and "forgiveness rather than permission". This is probably the single most significant

distinction between remediation efforts at civilian sites and "military" installations.

However, DoD's program is beset with many weaknesses, some of which could compromise the entire defense environmental effort. First and foremost of these is inadequate coordination and centralized management of the services' environmental programs.

> Lacking the guidance and unifying force behind ... reporting requirement(s), there has been no unified reporting of military toxic releases. Instead, regulators and the public have been presented with Pentagon waste generation figures that are more like "guestimates" than hard numbers that such a serious issue demands.[33]

The principle reason for this shortfall is a lack of centralized control at DoD. Reporting procedures are different within and across the several services, with no standard binding their efforts together. The DERP does not provide specific enough guidance to solve this problem. **The result:** *DOD does not know the magnitude, toxicity, nor migration destinations of its hazardous wastes. This uncertainty impedes efficient cleanup efforts and programming of limited environmental dollars.*

Another significant shortfall is in the legal arena. The principle of "sovereign immunity"[34] and the "unitary theory of the executive"[35] preclude prosecution of DoD by stakeholders (individuals and private concerns) and

executive agencies. The Justice Department contends that Federal Agencies are exempt from state (and local) enforcement under the doctrine of "sovereign immunity" and has refused to bring enforcement suits (on behalf of the EPA) against DoD, claiming that the "unitary theory of the executive" precludes one agency of the executive branch (EPA) from suing another (DoD).[36] The practical result of these views is that there is no downside risk for the Defense Department in this very sensitive area. Without the specter of liability from litigation, a major force in the civilian environmental market, DoD can set its own agenda concerning site remediation, cleanup, and closure. In these times of budgetary constraints, fiscal crisis, and military cutbacks, limited resources are understandably directed at mission essential tasks and away from the DERP. **The result:** *sites remain contaminated, contaminants continue to migrate off-site, and stakeholders have no legal mechanism through which they can influence the cause of the problem.*

Our military's environmental record is less than sterling. Past practices and environmental ignorance have caused significant ecological harm and continue to pose risks to human health. Present DoD programs, though based in an action organization which speaks well for remediation and process innovation, fall short of providing the

information and opportunities necessary for credible management of this critical problem. Consequently, the need for a lead agency, such as the Corps, in managing this technological innovation is key.

III. REMEDIATION TECHNOLOGIES

> . . . farsighted peacetime military innovation has bee.. possible in the American military, even during the 1920s and 1930s when military budgets were tight and popular attitudes toward the military were far from friendly, and even in the 1950s, when the military bureaucracy had swollen in size far beyond prewar levels[37]. . . Study of the changes in the economic, political, or technological realms that were beyond the control of governments and that constituted the environment with which military organizations had to contend could provide a more stable basis for deciding whether military innovation was necessary and what its character might be.[38]

As Rosen suggests, innovation is possible in the most hostile of peacetime environments. Moreover, for military organizations to continue to be viable means to political ends, innovation must occur. This innovation based, however, upon a knowledge of the underlying strategic environment and a model of the forces which drive innovation in general. To this end, our center of gravity with regard waste remediation is the base of technologies presented here. However, our operational center of gravity in the more holistic domain of technological-tactical crossover, is cybernetic, that is, the management of these technologies toward that strategic political objective. This is the value-added innovation role of the US Army Corps of Engineers; to innovate by creatively combining and managing remediation technologies for optimum result.

Hazardous Waste Remediation, or "end-of-pipe" cleanup, is generally accomplished by using one or more of three (3)

types of systems: 1) in situ, 2) prepared bed, and 3) in-tank reactor. **In situ** systems involve treating contaminated soils in-place, that is, where the contamination is located; contaminated soil is not moved from the ground. **Prepared bed** systems involve either 1) the physical removal of contaminated soil from its original site to a newly prepared area which has been designed to enhance treatment and/or prevent transport of contaminants from the site, or 2) movement of contaminated soil from the site to a storage area while the original location is prepared for use, after which the soil is returned to the bed, where treatment is accomplished. **In tank** systems involve removal of contaminated soil for treatment in an enclosed reactor based upon batch, complete mix, or plug flow systems.[39]

These three (3) systems employ one or more of several treatment technology classes: 1) biological, 2) chemical, 3) physical separation (component and phase), 4) stabilization, solidification, encapsulation, and 5) thermal.

Biological[40] treatment (Table 1) involves employing bacteria, fungi, and/or microorganisms to alter or destroy the hazardous waste. Liquid and solid wastes that can be treated by this method may include toxic chlorinated and aromatic organic compounds. The process is highly sensitive to environmental conditions, including fluctuations in pH

and temperature, and to changes in the concentrations of heavy metals and salts in the waste stream.

Chemical[41] treatment (Table 2) of hazardous waste is accomplished through a chemical reaction in order to destroy the hazardous component. Wastes that can be treated by this method include both organic and inorganic compounds without heavy metals. Drawbacks to this method include the inhibition of the treatment process reaction by impurities in the waste and the potential generation of hazardous byproducts.

A **physical**[42] treatment (Tables 3 and 4) separates the hazardous waste from its carrier by various physical methods such as adsorption, distillation, and filtration. This class of treatment is applicable to a wide variety of wastes but further treatment is usually required.

Stabilization, Solidification, and Encapsulation[43] processes (Table 5) isolate wastes from the surrounding environment without destroying their hazardous constituents. The treatment objective is normally achieved by mixing the waste with an inorganic compound such as fly ash, lime, clay, or Portland cement to form a chemically and mechanically stable solid. The treated waste generally has higher strength, lower permeability, and lower leachability

than the untreated waste. This treatment class is applicable primarily to inorganic wastes containing heavy metals. Organic compounds often interfere with the setting action of the solidifying agent. There is no guarantee of the effectiveness of this method over time due to a lack of data on long term leachability studies. This type of treatment may be feasible for use at sites with limited space or in emergency actions to alter the form of the waste to a more easily transportable form.

Thermal[44] treatment (Table 6) involves the decomposition of waste by thermal means into less hazardous or nonhazardous components. When subjected to high temperatures (2500-3000°F), organic wastes decompose to similar, less toxic forms. Complete combustion yields carbon dioxide and water plus small amounts of carbon monoxide, nitrous oxides, and chlorine and bromine acid gases. Some thermal processes produce "off gases" and ash that require further treatment or landfill disposal. This treatment class is most suitable for organic wastes and is less effective when attempting to detoxify heavy metals and inorganic compounds. Thermal treatment is often very expensive.

Treatment technologies and systems may be combined to form chemical- and site-specific *treatment trains*, which can

be selected to address specific waste escape pathways and phases during remediation. Evaluation for each possible combination of technologies and systems is based on a chemical mass balance approach through time to identify the fate of each waste. However, the lack of approaches for this sort of evaluation remains a current, major deficiency in the area of subsurface remediation, including soil remediation. In fact, two major problems with regard to meeting soil remediation requirements have been 1) lack of availability of appropriate technologies, and 2) lack of methods and approaches for evaluating and selecting remedial technologies for specific site-waste scenarios, especially with regard to *in situ* remediation.[45]

Alternative technologies for each of the five (5) treatment classes are presented in Tables 1 through 6. Applicable waste types, practical limitations, and special use considerations are also included. The development phases described for each technology are as follows: ***A****=Available Alternative Technology* indicates that a technology is fully proven and in routine commercial or private use; ***I****=Innovative Alternative Technology* describes a technology for which cost or performance information is incomplete, thus hindering routine use at hazardous waste sites (An innovative Alternative Technology requires full-scale field

testing before it is considered proven and available for routine use); ***E**=Emerging Alternative Technology* signifies that the technology has not yet successfully passed laboratory or pilot-scale testing.[46]

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHA	MOB
Activated Sludge	Soluble organics in dilute aqueous streams (<1% suspended solids)	• BOD <11,000 ppm. • Requires low concentrations of heavy metals, PCBs, pesticides, oil, and grease	A	X
Aerobic Treatment (sequential batch reactor, fluidized bed, fixed film fluidized bed with / without activated carbon, aerated biofilm reactor, membrane reactor)	Aqueous waste with low levels of nonhalogenated organics and certain halogenated organics (that is, phenols, formaldehyde, PCP).	• BOD <10,000 ppm. • Requires consistent, stable operating conditions.	A	X
Anaerobic Treatment (fluidized bed, fixed film fluidized bed with / without activated carbon).	Aqueous slurry with low to moderate levels of nonchlorinated organic compounds containing <7% solids.	• Requires consistent, stable operating conditions. • Unsuitable for oil and grease, aromatics, and long chain hydrocarbons.	A	
Bacteria	PCBs and various other organic compounds in soils (that is, 2,4,5-T and 2,4-D).	• May involve genetic engineering. • Natural adaptation.	A	X
Composting	Aqueous sludge with <50% solids, nonchlorinated hydrocarbons, high organic wastes including oils, tars, and industrial processing sludges.	• Requires nutrient supplementations. • Output sludge contains heavy metals.	A	
Enzyme Treatment	Soluble organics in dilute aqueous waste streams.	• Requires stable influent concentration.	E	X
Lagoons and Ponds	Industrial wastewater, organics with slow biodegradation potential, soluble organics in dilute aqueous waste streams.	• Requires large areas. • Unsuitable for solids. • Requires temperate climate. • Output sludge contains heavy metals and refractory organics which require further treatment.	A	
Mycorrhizas	Soil - entrained hazardous waste constituents.		E	X
Rotating Biological Contactor	Biodegradable dilute aqueous organic waste including solvents and halogenated organics.	• Limited to low concentrations of heavy metals and concentrated refractory organics. • Unsuitable for sludges or solids.	A	X
Trickling Filter	Soluble organics in dilute aqueous streams with <1% suspended solids including solvents and halogenated organics.	• BOD <5,000 ppm. • Output sludge contains heavy metals and refractory organics which require further treatment.	A	X
White Rot Fugus *(Phanerochaete chrysosporium)*	Toxic or refractory halogenated organics in soil (that is, 2,3,7,8-TCDD, DDT, mirex, lindane, hexachlorobenzene).		E	X
Yeast Strains	Halogenated organics.	• Involves genetic engineering.	E	X

PHA - Phase of Development; **A** = Available, **I** = Innovative, **E** = Emerging
MOB (MOBILE) - Transportable

Table 1.
Biological Treatment Technologies.

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHA	MOB
Chlorinolysis	Concentrated liquid chlorinated organic waste streams with low concentrations of sulfur and oxygen.	• Unsuitable for solids and tars. • Unsuitable for benzene and aromatics. • Output carbon tetrachloride can be recovered.	I	
Dehalogenation (including use of the Alkali Metal Polyethylene Glycol Reagent - APEG).	Halogenated organics in soils and sludges that are partially dehydrated (that is, PCBs, dioxins).	• Requires heat and excess reagent.	I	X
Electrochemical Dehalogenation	Halogenated organics (that is, PCBs).	• Not known.		E
Electrolytic Oxidation	High concentration cyanide (10%) and metals wastes.	• Suitable for low solid content wastes.	A	
Hydrolysis	Solids, soils, sludges, slurries, or liquids contaminated with organic compounds.	• Requires careful handling of strong acids and alkalines. • Reaction is performed at high temperatures and pressure requiring close monitoring.	A	X
Ion Exchange	Aqueous organic or inorganic waste streams, principally metals.	• Suitable for liquid waste only.	A	X
Lignin Adsorption	Aqueous organic or inorganic waste streams.	• Not known.	E	X
Neutralization	Corrosive liquid wastes, both acids and bases.	• Unsuitable for sludges and solids. • Requires corrosion resistant equipment.	A	X
Oxidation (chlorination, ozonation, hydrogen peroxide, potassium permanganate, chlorine dioxide, hypochlorites).	Dilute aqueous waste (<1% waste) containing organic / inorganic compounds.	• Requires controlled reaction conditions. • Suitable for liquids and sludges only.	A	X
Polymerization	Organic compounds such as aromatics, aliphatics, and oxygenated monomers.	• Application is limited to spills.	I	X
Precipitation	Aqueous organic and inorganic waste containing metals.	• Requires optimization of the reaction pH for the specific mix of metals present. • Output sludge requires further treatment. • Cross - reactivity may occur for mixed - metals content waste. • Unsuitable for sludges, tars, and slurries.	A	X
Reduction (Sulfur dioxide, sodium borohydride sulfite salts, ruthenium tetraoxide).	Dilute aqueous waste stream containing inorganic compounds, especially metals (<1% heavy metal concentration).	• Applicable to inorganic waste only. • Suitable for liquid waste only.	I	X
UV / Photolysis	Liquid waste containing dioxins.	• Suitable for liquid wastes only.	E	X

PHA - Phase of Development; **A** = Available, **I** = Innovative, **E** = Emerging
MOB (MOBILE) - Transportable

Table 2.
Chemical Treatment Technologies.

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHA	MOB
Air Flotation (dissolved or induced)	Liquid waste containing oils or light suspended solids.	• Liquid effluent may require further treatment.	A	X
Centrifugation (bowl, basket, disk).	Organic / inorganic liquids, slurries, and sludges containing suspended or dissolved solids or liquids where one component is nonvolatile. For example, wastewater sludge, wastes containing immiscible liquids, or wastes containing three (3) distinct phases.	• Unsuitable for tars, solids, dry powders, or gases. • Not applicable for small size or low density particles.	A	X
FILTRATION:				
Belt Filter Press	Biological and industrial sludges.	• Filter cake may require further treatment.	A	X
Chamber Pressure Filtration (pressure leaf, tube element, plate and frame, horizontal plate)	Wastewater sludges, or sludges with a flocculated or adhesive nature.	• Dewatering technology. • Unsuitable for sticky or gelatinous sludges.	A	X
Granular Media Filtration	Liquid waste containing suspended solids and / or oils.	• Requires frequent backwashing. • Requires pretreatment for suspended solids with concentration <100 mg/l.	A	X
Vacuum Filtration (fixed media, rotary drum)	Organic or inorganic chemical sludges, metals, and cyanides bound up in hydroxide sludges.	• Dewatering technology. • Unsuitable for sticky or gelatinous sludges.	A	X
Gravity Separation (coagulation, flocculation, sedimentation)	Liquid waste containing settleable suspended solids, oils, and / or grease.	• Liquid effluent may require further treatment. • Unsuitable for heavy slurries, sludges, or tars.	A	X
***In Situ* Soil Extraction**	Soils with low levels of organics or inorganics / metals contamination.	• Unsuitable for dry or organic - rich soils.	E	X

PHA - Phase of Development; **A** = Available, **I** = Innovative, **E** = Emerging
MOB (MOBILE) - Transportable

Table 3.
Physical Treatment Technologies
(*Component Separation*).

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHA	MOB
Air Stripping	Aqueous and adsorbed organic and inorganic wastes with relatively high volatility and low water solubility such as chlorinated organics, aromatics, and ammonia.	• Limited to VOC concentration < 100 ppm. • Suspended solids may clog tower.	A	X
Carbon Adsorption	Aqueous organic wastes (containing < 1% total organics and < 50 ppm solids) with high molecular weight and boiling point, and low water solubility, polarity, and ionization.	• Unsuitable for metals. • Unsuitable for oil and grease.	A	X
Colloidal Gas Aphrone (CGAs) (enhances air stripping and biodegradation).	Soils contaminated with phenols, phthalate esters, aromatic hydrocarbons, aliphatic hydrocarbons, chlorinated hydrocarbons, amines, and alcohols.	• Hydraulic conductivity of the soil must be $> 10^{-4}$ cm/sec.	E	X
Distillation	Liquid organic mixtures with low viscosity that can be separated due to molecular weight / volatility differences.	• Unsuitable for thick polymeric materials, slurries, sludges, or tars.	A	X
Electrokinetics	Soils contaminated with organic or inorganic waste.	• Soil matrix must be relatively permeable and saturated.	I	
Evaporation	Organic / inorganic liquid solvents contaminated with nonvolatile impurities (that is, oils, grease, paint solvents, polymeric resins).	• Liquids must be volatile. • Unsuitable for tars, solids, dry powders, or gases. • Energy - intensive process.	E	X
Freeze Crystallization	Dilute aqueous organic / inorganic waste solutions containing < 10% total dissolved solids.	• Unsuitable for foamy, viscous, or high solid content waste streams.	E	X
Mechanical Soil Aeration	Volatile organics in sludge and soil.	• Effluent may require further treatment.	A	X
Metal Binding	Metal - contaminated aqueous streams, leachate, or groundwater.	• Limited to metal concentrations between 500 - 1000 ppm.	E	
Resin Adsorption	Aqueous waste streams containing soluble organics, particularly phenols and explosive materials.	• Limited to low concentrations of organics (< 8%) and suspended solids (< 50 ppm).	A	
Reverse Osmosis	Aqueous waste streams containing < 400 ppm heavy metals, high molecular weight organics, and dissolved gases.	• Unsuitable for oxidants. • Requires controlled pH, low concentration of suspended solids.	I	X
Solvent Extraction	Aqueous stream contaminated with single - or multi - component dissolved organic wastes. Sludge contaminated with oils, toxic organics, and heavy metals.	• Extracting solvent must be immiscible in the liquid and differ in density so gravity separation is possible. • Suitable for sludges containing < 20 wt % oil / organics and < 20 wt % solids.	A, I	X
Steam Stripping	Aqueous solutions of volatile organics.	• Effluent may require further treatment. • Suitable for waste streams with low metal concentration.	A	X
Supercritical Extraction	Sludge, solids, or liquids contaminated with organics.	• Effluent may require further treatment.	E	X
Ultrafiltration	Removes oils, metals, and proteins from aqueous solutions with dissolved organics, emulsions, and colloidal particles.	• Limited to low concentrations of suspended solids.		

PHA - Phase of Development; **A** = Available, **I** = Innovative, **E** = Emerging
MOB (MOBILE) - Transportable

Table 4.
Physical Treatment Technologies
(*Phase Separation*)

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHA	MOB
Cement - based Fixation	Treated sludges and soils containing metal cations, radioactive wastes, and solid organics (that is, plastics, resins, tars).	• Long term stability / leachability is unknown. • Lignite, silt, and clay increase setting time. • Dissolved sulfate salts, borates, and arsenates must be limited.	A	X
Macro - Encapsulation, Overpacking, Thermoplastic and Thermosetting Techniques	Chemically or mechanically stabilized organic, inorganic, and radioactive wastes.	• Encapsulating matrix must be compatible with waste. • Long term leachability unknown, therefore, waste storage must be considered. • Requires specialized equipment.	A	X
Pozzolanic - based Fixation (fly ash, lime based)	Treated sludges and soils containing heavy metals, waste oils, solvents, and low level radioactive waste.	• Borates, sulfates, and carbohydrates interfere with the process. • Long term stability / leachability is unknown.	A	X
Sorptive Clays (treated, chemically modified)	Halogenated organic compounds and heavy metals.	• Long term leaching is a problem, therefore, waste storage must be considered.	I	X
Vitrification	Soils contaminated with organic, inorganic, and radioactive wastes.	• Limited to soils with high silica content.	A, I	X

PHA - Phase of Development; **A** = Available, **I** = Innovative, **E** = Emerging
MOB (MOBILE) - Transportable

Table 5.
Stabilization, Solidification, and Encapsulation Treatment Technologies.

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHA	MOB
Electric Reactor	Soil contaminated with solid and liquid organics and inorganics.	• Contaminated soil must be finely divided and dry.	I	X
Fixed Hearth	Bulky solids, liquids, and sludges.	• Particle size must be large enough not to fall through grate.	A	
Fluidized Bed	Organic solids, liquids, and sludges	• Requires low water and inert solid content.	A	X
Industrial Boiler	Granulated solids, liquids, and sludges.	• Requires low chlorine and sulfur content. • Ash content clogs system. • Small particle size.	A	
Industrial Kiln	Spent pot lining, nonhalogenated oils, and PCB - contaminated liquids and sludges.	• Requires low chlorine and sulfur content.	A	
Infrared Incineration	Soils, solids, and sludges contaminated with organic compounds (that is, PCBs, dioxins, explosives).	• Primarily for solid organic waste. • Heavy metals are not fixed in ash.	A	X
Liquid Injection	Pumpable liquid organic waste.	• Unsuitable for inorganic content and heavy metal content wastes. • Chlorinated solvents cause accelerated corrosion rates.	A	X
Molten Glass	Organic solids, liquids, gases, sludges (that is, plastics, PCBs, asphalt, pesticides).	• Sodium sulfates must be limited to < 1% content. • Inappropriate for soils and high ash content waste.	I	
Molten Salt	Low ash content waste, low water content liquid, or solid waste.	• Corrosion problems. • Requires frequent bed replacement.	I	X
Multiple Hearth	Granulated solids, sludges, tars, liquids, and gaseous combustible waste.	• Water, salt, and metal content must be limited. • Particle size must be small enough to pass through injector nozzles. • Not recommended for hazardous wastes.	A	
Plasma Systems	Liquid organic wastes (that is, pesticides, dioxins, PCBs, halogenated organics).	• Liquids only.		X
Pure Oxygen Burner	Liquid wastes which require high temperatures for destruction or have low heating values.	• Requires specially engineered nozzles to atomize the liquid waste.		X
Pyrolysis	Viscous liquids, sludges, solids, high ash content materials, salts and metals, and halogenated waste.	• Requires homogeneous waste input. • Metals and salts in the residue can be leachable.		X
Radio Frequency Thermal Heating	Volatile, low boiling point, or easily decomposed organic compounds in soil.	• Not known.	I	X
Rotary Kiln	Solid, liquid, or gaseous organic waste.	• Containerized wastes are difficult to handle. • High inorganic salt or heavy metal content wastes require special consideration. • Fine particulate matter must be limited.	A	X
Supercritical Water Oxidation	Aqueous organic solution / slurry or mixed organic / inorganic waste.	• Not known.	I	X
Wet Air Oxidation	Aqueous waste streams (< 5%) with dissolved or suspended volatile organic substances.	• Unsuitable for solids, viscous liquids, or highly halogenated organic compounds. • Not economical for dilute or concentrated waste.	A	X

PHA - Phase of Development; **A** = Available, **I** = Innovative, **E** = Emerging
MOB (MOBILE) - Transportable

Table 6.
Thermal Treatment Technologies.

IV. CONCLUSIONS AND IMPLICATIONS

WORST POLLUTER

As the discovery process continues, more and more contaminated "hot spots" will be uncovered. The problems surrounding currently identified sites will continue to confound decision makers if immediate and effective response actions are not effected. Cleanup of contaminants from the past is only part of the solution, however. Process and program overhaul to effectively monitor and manifest the disposal of currently generated wastes must be implemented. Waste minimization strategies, such as those outlined in the Five-year Integrated Hazardous Material/Hazardous Waste Management Plan must also be brought to fruition; end-of-pipe treatments are well known to be more expensive and environmental unsound than process modifications to reduce waste generation at its sources. Substitution of less toxic substances in processes is a step in the right direction.

Scaling down military programs and operations in recognition of the decreased strategic Soviet threat around the world is already in the works. From the environmental standpoint, this could be a boon to the effort of reducing military environmental destruction. However, it is a precarious assertion that this alone will allay further

damage or even greatly diminish it. DoD must design into its daily activities a consideration for environmental matters. Not only must the industrial processes of weapons and chemicals manufacture be realigned along environmentally sound lines, so must maintaining the readiness of the force. Soldiers and sailors must be educated, as should their civilian counterparts, to respect environmental concerns. They will use this knowledge as members of our armed forces to help change its course to a more environmentally enlightened path. They will also carry this knowledge back with them when transitioning from military to civilian careers as their service obligations terminate. Losing this mechanism for environmental action, both inside and outside of the military, would be criminal.

MILITARY'S PROGRAM HAS PROBLEMS

The Defense Department's hazardous waste cleanup programs are beset with problems which, unresolved, will further hinder efforts towards timely and effective solutions. Standardized reporting procedures and ingraining a bone-deep environmental ethic are critical to success. In addition, the legal issues of "sovereign immunity" and "unitary theory of the executive" must be addressed. Litigation is not the key, however, as it is, historically, a stumbling block to swift environmental remedy.

Interagency agreements, as outlined in the IRP, may be the tool through which stakeholder concerns can be equitably addressed. The critical issue, as with Superfund sites, is a balance between litigation, regulation, and remedy. The Superfund program has failed in this regard, placing too much faith in tort law as the enforcement/compliance vehicle. DoD is in a unique position to establish such a balance and, perhaps, develop a model after which other NPL sites across the country could pattern their remediation programs.

MILITARY'S PROGRAM MUST BE CREDIBLE

The Defense Department cannot hide behind the veil of national security in pursuing its environmental end state. If it is to succeed, it must be considered credible by the stakeholders involved -- lawmakers, environmental groups, the scientific community, and local concerned citizens. This should involve a more participatory approach, specifically, the Co-production model described by Susskind and Elliot.[47] Presently, the action for public involvement is delegated to local commands' Public Affairs Offices. As a risk mitigation tool, as well as a joint fact-finding and education vehicle, commanders must further interact with stakeholders to ensure their support and confidence, up front. However, public participation and stakeholder

involvement should not hinder DoD's environmental response. Credibility is earned from results and deeds, not rhetoric and hand waving. DoD has the opportunity to materially effect the environmental health of the nation, in a positive way, and should realize that all parties' concerns will necessarily not be satisfied, as they conflict in many regards. Action, not deliberation, is the key.

Our military's toxic legacy is one of immense proportions. As bases are closed and the size of the force is scaled back in response to the decreasing strategic threat from abroad, "peace dividends" will be targeted at environmental restoration. Because of its action orientation and insolation from the liability of litigation, DoD and the Corps have a unique opportunity to foster innovation of remediation technologies at contaminated military sites. Part and parcel to this is developing new and innovative action programs and technologies for transfer directly to private sites. As the nation's engineers and action agent for DA's programs, the US Army Corps of Engineers can help generate the success stories necessary to sell the Congress on assigning them the nation's overall remediation mission. With the "big blip on the screen" (1995 Superfund Reauthorization) not too far away, this should be a primary focus for the Corps in the near term.

In the long-term, the consideration should shift to commercialization and practical application of new remediation technologies and action programs to help bolster our domestic contractor and technology bases, further enhancing our competitiveness in global circles.

THE US ARMY CORPS OF ENGINEERS

The US Army Corps of Engineers has a distinct responsibility and unique aptitude to assume a leadership role in resolving this environmental dilemma. The Corps has both the moral and professional responsibility for providing, at the least, technically and scientifically feasible alternatives to the Nation. Over a century of experience in solving tough problems and working with local governments and the business community speak highly for its role as an intermediary and coordinator in just such an effort. In addition, the Corps is a stable, government organization, capable of bearing significantly more financial and operating risks than even the largest of America's corporations. If for no other reason than this, the Corps is an ideal vehicle for insurance underwriting and for information gathering at significantly reduced costs. Both the opportunity costs of inaction and those of misguided actions can be mitigated in this reduced risk arena.

Achieving goals means applying science to situations the best way we know - in other words, taking risks.[48] The Corps' capacity to assume considerable risks in developing solutions for unique problems is particularly noteworthy when considering the environment. Remediation of hazardous chemical wastes and disposal of spent nuclear fuels are inherently uncertain propositions. Private investment in any one of these endeavors is at significantly higher cost and requires equally substantial return on investment. Our increasingly litigious society makes such ventures nearly impossible, especially for smaller contractors attempting to penetrate the market with innovative products or processes. Without some sort of subsidy, the market will tend to force new players from the scene and encourage overall inefficiency. It is here that the Corps can assume a leadership role in technological innovation and privatization of remediation processes. Through alternative procurement mechanisms, such as design-build or other turnkey approaches, the Corps can mitigate market risks. It can also pursue traditional competitively bid contracts for innovative projects, but hold contractors liable only to the limits of the contract, not to the standards of processes yet to be developed. In so doing, contractors are *de facto* indemnified if a new energy or remediation technology fails

with the Corps assuming *ex post facto* risks of technological failure. Therefore, the technology is at risk, not the contractor. Such a method delivers the needed subsidy in the form of risk mitigation resulting in correspondingly lower costs of capital, bid bonding, and performance insurance. Overall contract costs are lower with, in the case of alternative procurement mechanisms, constructability engineered directly into the design making the final product more sound, both technically and financially. Innovative technologies for hazardous waste remediation brought to the market at a lower cost and quicker, provide more and better information to our national policy makers and scientists for even more informed and legitimate decisions.

As the nation's engineers, the Corps also has a responsibility for developing new and better technologies to allay the environmental consequences of industrial activities. Our new found public awareness concerning the environment has not yet been translated into remedial action on a large enough scale to effect real change. Now, more than ever, engineering skills and tools are needed to achieve environmental ends.[49] However, engineering is not simply the technical proposal of new and innovative methods and mechanisms. Part and parcel to engineering solutions is economic feasibility. A properly prepared engineering

solution is the optimal combination of technical alternatives and available economic resources. Ultimately, engineers must present their solutions in a format acceptable to audiences of diverse political convictions and scientific aptitudes. This is the forte, and mission, of the Corps.

Engineering skills and tools are abundant within the Corps, both at its operating engineering divisions and in its three (3) central laboratories. Also organic to the organization are the construction elements of each division which actually administer contracts around the world. The synergy of using both to effectively manage the development of new and better technologies and remediation programs for our common environmentally safe future is obvious. Balancing tasks and budgets is a daily function within the Corps, one which it takes seriously, along with presenting engineering solutions at public forums, a common part of all civil works projects. Above and beyond this is the fact that the Corps is an agent of our government and its national policies. It has its "finger on the pulse" of national sentiment and our policy makers' desires, along with understanding its greater task of maintaining the Nation's trust. The Corps is central to coordinating the

engineering solutions to our environmental problems and presenting them to our Nation.

RISK MITIGATION

The *test bed* or *incubator* concept is, in fact, an innovative risk mitigation strategy designed to shift the uncertainty in remediation projects to the party most able to bear them; in this case, the government. With industry's emphasis on short-term return on investment and our high domestic cost of capital, the risks associated with remediation contracts often make only a very few projects financially feasible. This is especially true when conventional contracting mechanisms, such as fixed price/competitive bid, are employed. Through the use of alternative contracting methods, or innovative uses of the conventional ones, the biddability and constructability risks associated with remediation jobs will be reduced. Coupled with the test bed concept's long-term focus on development and commercialization of new processes, the risks of implementing innovative methods will be shifted from contractors to the government. This will, in turn, increase the competitiveness of our domestic contractor base in the global remediation market.

"TEST BED" OR "INCUBATOR"

The magnitude of our military's toxic inventory and the number of DoD sites presently listed for further remedial action speak well for using this arena as a *test bed* or *incubator* in developing new and innovative remediation technologies and administrative procedures. This simultaneous program of remediation and R&D should be an explicit DoD policy objective and an integral part of the DERP and the IRP. Lessons learned from other environmental programs (Superfund, for example) should be drawn upon in this regard. Emphasis should be on action rather than study to mitigate the environmental opportunity costs of a delayed response, whether caused by the lack of appropriate technologies or bureaucratic inertia in the name of scientific deliberation. Newly developed action programs and remediation technologies could be directly transplanted to similar civilian sites to help streamline cleanup. Alternatively, the US Army Corps of Engineers, as the agent of innovation in the DoD toxic arena, could be given universal oversight, responsibility, and resources for the nation's remediation responsibilities.

CONSTRUCTION INDUSTRY POTENTIAL

If the federal government adopts the policy prescribed above, private industry construction contractors will be some of the primary beneficiaries. Since the Corps has no

organic construction forces properly trained and equipped for remediation of hazardous waste sites, work will be performed exclusively by civilian firms. As described in Appendix D, the market potential for these firms is great. However, the size of the market is not the only factor to be considered at this point. Hazardous waste remediation projects will also help to mitigate the construction industry's cyclical nature by reducing the risks firms face when bidding contracts in fading conventional markets. With the protection and encouragement of the federal government, contractors will develop "field proven" remediation technologies and construction processes to secure other cleanup projects, both military and civilian. Combining these new jobs with others of conventional fare in their portfolios, firms will effectively diversify their operating risks. As a result, they will be more able to compete in global markets where "court ready" remediation technologies and construction management services are also in high demand.

NATIONAL TECHNOLOGY STRATEGY

With implementation of the *test bed* or *incubator* concept, DoD will lay the foundation of a national technology strategy focusing on commercialization of innovative processes. The intent is to afford construction

firms an opportunity to develop, field test, and refine new remediation technologies for future injection into the industrial mainstream, while shielded from foreign competition. Government protection, while these contractors worked on DoD projects, would amount to a subsidy for product and process development where firms could, less expensively, bring new techniques to market and compete on equal terms with offshore companies, especially where large capital outlays for equipment are required. Cost engineering will be critical in this regard, as contractors continue to refine technologies and construction methods to increase their efficiency and reduce costs. If our firms attack this market as "first movers", they will surely fall prey to "fast follower" nations, such as Japan, who are extremely adept at competing by learning from the first movers' mistakes and improving on their processes. If we are to compete, at all, in such a competitive environment, some national strategy for introduction of new technologies must be developed and employed. The *test bed* or *incubator* concept is exactly how such a strategy will be realized.

INDUSTRIAL TECHNOLOGICAL INNOVATION

Managing technological innovation is the value-added cybernetic strength upon which the US Army Corps of Engineers will foster industrial-tactical crossover. Innovation in construction functions, specifically hazardous waste remediation, portends greater implications for technological development and tactical application. Peacetime innovation necessarily involves organizational change. Technological innovation is strongly characterized by the need to develop strategies for managing uncertainty.[50] The cybernetic function of managing technology for industrial application represents the dynamic between the two and will help us think more holistically about developing and using technology in general. It will also help us understand the subtle yet powerful forces driving innovation in the private sector for application at the tactical level. As a result, we can develop strategies and campaign plans for tactical technological innovation. This is the essence of our operational art, that is, 1) tying strategy with tactics and 2) creating the conditions for quick and decisive tactical victory through, among other things, doctrinal and technological superiority. Domestic contractors are key in this regard to both the military (in the new technologies they provide) and national competitiveness abroad (in the strength of our national

technology base). Understanding this, we can balance our tactical technological needs with our national technology strategy. Consequently, the Corps' hazardous waste remediation efforts have broader Army-wide implications for understanding how we should innovate technologically (physical domain of battle) and how we should manage it (cybernetic domain).

Appendix A: DEFINITIONS[51]

Administrative Record Compilation of documents that records the decision making process regarding the selection of a response action to be taken at a site.

Applicable Requirements Cleanup Standards, standards of control and other substantive environmental protection requirements, criteria or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location or other circumstances at a CERCLA site.

Baseline Risk Assessment An evaluation of the potential threat to human health and the environment in the absence of any remedial action at a site.

Bench Studies Treatability tests performed on a small scale, usually in a laboratory, to better define parameters of a treatment technology.

Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) Also *Superfund* Amended in 1986 by the Superfund Amendments and Reauthorization Act.

Competitive Evaluation Plan A plan which describes how technical proposals submitted by potential contractors will be evaluate.

Contracting Officer Individual with the authority to enter into, administer and/or terminate contracts and make related determinations and findings.

Contracting Officer's Representative Individual trained to prepare procurement requests and monitor contractor performance. The Contracting Officer's Representative is not authorized to sign contracts or to make changes and modifications to a contract.

Data Quality Objectives Quantitative and qualitative statements that specify the data needed to support decisions regarding remedial response activities.

Decision Document Documentation of response action decisions for all actions at non-National Priorities List

Sites and for interim response actions at National Priorities List sites.

Defense Environmental Restoration Account A transfer account, established by the Defense Appropriation Act of 1984, that funds the Installation Restoration Program for active installations and the Formerly Used Defense Sites Program for formerly owned or used installations. The account also funds the other goals of the Defense Environmental Restoration Program.

Executing Agency The agency responsible for administering IRP activities for a site or installation.

Major (military) Innovation A change in the concept of operation of [a] combat arm, that is, the ideas governing the way it uses its forces to win a campaign . . . also [a] change in relation of that combat arm to other combat arms and a downgrading or abandoning of older concepts of operation and possibly of a formerly dominant weapon. Changes in the formal doctrine of a military organization that leave the essential workings of that organization unaltered do not count as an innovation by this definition.[52]

Potency Factor The lifetime cancer risk for each additional mg/kg body weight per day of exposure.

Potentially Responsible Party current and former owners or operators and persons who may be accountable for having generated hazardous substances or were involved in transport, treatment or have disposal of hazardous substances at a site under litigation.

Preliminary Assessment Initial analysis of existing information to determine if a release may require additional investigation or action.

Procurement Request Written justification for securing contract services.

Project Officer Individual that develops the Procurement Request, in this thesis to be considered the same individual as the Contracting Officer's Representative.

Public Involvement and Response Plan Document based on community interviews that specifies the community relations

activities that the Army expects to undertake during a response action.

Quality Assurance Project Plan (as stated in the National Contingency Plan) A written document, associated with remedial site sampling activities, which presents in specific terms the organization (where applicable), objectives, functional activities, and specific quality assurance and quality control activities designed to achieve the data quality goals of a specific project or continuing operations (or group of similar projects or continuing operations). Part of the Sampling and Analysis Plan that is prepared prior to any non-emergency site sampling activities.

Record of Decision Documentation of a final remedial response action decision at a National Priorities List site.

Reference Dose For a noncarcinogenic effects, the amount of a chemical that can be taken into the body each day over a lifetime without causing adverse effects.

Release (as stated in the CERCLA) Any spilling, leaking, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping or disposing into the environment (including the abandonment or discarding of barrels, containers and other closed receptacles containing any hazardous substance or pollutant or contaminant), but excludes (A) any release which results in exposure to persons solely within a workplace, with respect to a claim which such persons may assert against the employer or such persons, (B) emissions from the engine exhaust of a motor vehicle, rolling stock, aircraft, vessel, or pipeline pumping station engine, (C) release of sources, byproduct, or special nuclear material from a nuclear incident, as those terms are defined in the Atomic Energy Act of 1954, if such release is subject to requirements with respect to financial protection established by the Nuclear Regulatory Commission under Section 170 of such Act or, for the purpose of Section 104 of this title or any other response action, any release of source byproduct, or special nuclear material from any processing site designated under Section 102(a)(1) or 302(a) of the Uranium Mill Tailing Radiation Control Act of 1978, and (D) the normal application of fertilizer.

Relevant and Appropriate Requirements Cleanup standards, standards of control and other substantive environmental

protection requirements, criteria or limitations promulgated under Federal or State law, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location or other circumstances at a site, address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site.

Remedial Action or Remedy (as stated in CERCLA) Actions consistent with permanent remedy taken instead of or in addition to removal actions in the event or a release or threatened release of a hazardous substance into the environment, to prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health or welfare or the environment. The term includes, but is not limited to, such actions at the location of the release as storage, confinement, perimeter protection using dikes, trenches, or ditches, clay cover, neutralization, cleanup or released hazardous substances and associated contaminated materials, recycling or reuse, diversion, destruction, segregation of reactive wastes, dredging or excavations, repair or replacement of leaking containers, collection of leachate and runoff, on site treatment or incineration , provision of alternative water supplies and any monitoring reasonably required to assure that such actions protect the public health and welfare and the environment. The term includes the costs of permanent relocation of residents and businesses and community facilities where the President determines that, alone or in combination with other measures, such relocation is more cost effective than and environmentally preferable to the transportation, storage, treatment, destruction or secure disposition off site of hazardous substances, or may otherwise be necessary to protect the public health or welfare; the term includes off site transport and off site storage, treatment, destruction, or secure disposition of hazardous substances and associated contaminated materials.

Remedial Action Process Identification, evaluation, decision making and design and construction steps required to implement control measures. The remedial action process may lead to remedial actions, removals or decisions to take no further action.

Remedial Design Technical analysis and procedures which follow the selection of remedy for a site and result in a

detailed set of plans and specifications for implementation of the remedial action.

Remedial Investigation Process undertaken to determine the nature and extent of the problem presented by a release which emphasizes data collection and site characterization. The remedial investigation is generally performed concurrently and in an interdependent fashion with the feasibility study.

Removal (as stated in CERCLA) The cleanup or removal of released hazardous substances from the environment, such actions as may be necessary taken in the event of the threat of release of hazardous substances into the environment, such actions may be necessary to monitor, assess and evaluate the release or threat of release of hazardous substances, the disposal or removal material, or the taking of such other actions as may be necessary to prevent, minimize or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release. The term includes, in addition without being limited to security fencing or other measures to limit access, provision of alternative water supplies, temporary evacuation and housing of threatened individuals not otherwise provided for, action taken under Section 104(b) of this Act and any emergency assistance which may be provided under the Disaster Relief Act of 1974.

Response Action to remove, or undertake a removal, remedy or remedial action, including related enforcement activities.

Sampling and Analysis Plan Document composed of a Quality Assurance Project Plan and Field Sampling Plan that is prepared prior to site sampling activities.

Site A location on an installation where hazardous wastes have been stored, disposed, spilled or otherwise released to the environment. A site includes land and water resources where they are contaminated by the release, and it includes any structures, earth works or equipment that are clearly associated with the release. Where multiple sites may contribute to contamination of an aquifer or a common land area, the contaminated resource may be identified as a site that is distinguished from the sites where the releases occurred. A site is the basic unit for planning and implementing response actions.

Site Health and Safety Plan Document that specifies policies and procedures for ensuring the health and safety of personnel working at a site.

Site Inspection On-site inspection to determine whether there is a release of potential release and the nature of the associated threats. The purpose is to augment the data collected in the preliminary assessment and to generate, if necessary, sampling and other field data to determine if further action or investigation is appropriate.

Source Control Actions that either remove the source of contamination off-site or effectively contain it on-site so that continuing releases are prevented or reduced.

Tactical innovation A change in the way individual weapons are applied to the target and environment in battle.[53]

Technical Review Committee Committee composed of Army and EPA officials, State and local authorities and a public representative of the potentially affected community that reviews and comments on response actions and proposed actions at Army sites on or proposed for the National Priorities List or other major sites (those that present a significant threat to human health, welfare or the environment or cause public controversy).

Technological innovation Peacetime and wartime organizational innovation, is defined concerned with social innovation, with changing the way men and women in organizations behave. Technological innovation is concerned with building machines. Technological innovation introduces a new dimension to the relationship between one's own forces and the military organization of the enemy, a qualitative technological one. It introduces a new set of domestic actors, scientists, into the community within which military decisions are made. In short, technological innovation gives rise to an additional set of questions beyond those associated with organizational innovation.[54]

Technology Systematic knowledge and action, usually of industrial processes but applicable to any recurrent activity. [It] is closely related to science and engineering. Science deals with humans' understanding of the real world about them - the inherent properties of space, matter, energy, and their interactions. Engineering is the application of objective knowledge to the creation of plans,

designs, and means for achieving desired objectives. Technology deals with the tools and techniques for carrying out the plans.[55]

Third Party Site Privately or municipally owned storage, treatment and disposal sites that received hazardous wastes either from disposal contractors hired by the Army or directly from the Army. The Army, as a potentially responsible party, is designated as the third party in cases where enforcement actions to recover costs of cleanup is initiated. EPA, as the first party, cannot sue the Army to recover such costs, but nonfederal potentially responsible parties, as the second party, can.

To Be Considered Requirements Non-promulgated advisories (such as reference doses or potency factors), criteria and guidance issued by Federal and State governments that are identified to supplement applicable or relevant and appropriate requirements.

Appendix B: GLOSSARY[56]

AEO	Army Environmental Office
ARARs	Applicable or Relevant and Appropriate Requirements
CAA	Clean Air Act
ADARS	Army Defense Acquisition Regulation Supplement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 *aka* SUPERFUND
CFR	Code of Federal Regulations
COE	Corps of Engineers
DA	Department of the Army
DASD(E)	Deputy Assistant Secretary of Defense (Environment)
DEMIS	Defense Environmental Management Information System (replaces the Defense Environmental Reporting System)
DERF	Defense Environmental Restoration Fund
DERP	Defense Environmental Restoration Program
DoD	Department of Defense
DoE	Department of Energy
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	The Environmental Protection Agency

FIFRA	The Federal Insecticide, Fungicide, and Rodenticide Act
FS	Feasibility Study
FUDS	Formerly Used Defense Sites
FWPCA	The Federal Waster Pollution Control Act *aka* The Clean Water Act (CWA)
HM/HW	Hazardous Material/Hazardous Waste
HRS	Hazardous Ranking System
IAG	Interagency Agreement
IG	Inspector General
IR	Installation Restoration
IRP	Installation Restoration Program
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NFRAP	No Further Response Action is Planned
NPL	National Priorities List
O&M	Operations and Maintenance
OHW	Other Hazardous Waste
PA	Preliminary Assessment
PA/SI	Preliminary Assessment/Site Investigation
PRP	Potentially Responsible Party
RA	Remedial Action
RD	Remedial Design

RD/RA	Remedial Design/Remedial Action
RCRA	Resource Conservation and Restoration Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RPM	Remedial Project Manager
SARA	Superfund Amendment and Reauthorization Act
SDWA	The Safe Drinking Water Act
SI	Site Investigation
SSI	Screening Site Inspection
TSCA	The Toxic Substances Control Act
US	United States
USA	United States Army
USACE	United States Army Corps of Engineers
USACE/MRD	United States Army Corps of Engineers, Missouri Rivers Division
USATHAMA	United States Army Toxic and Hazardous Materials Agency
UXO	Unexploded Ordnance

Appendix C: STRATEGIC MARKET ANALYSIS

Commercial application of the remediation technologies and treatment trains available cannot be successfully effected without first understanding the structure of the Hazardous Waste Management industry and the competitive forces at work. This appendix to **III. <u>REMEDIATION TECHNOLOGIES</u>** is based upon Michael E. Porter's *Value-Added Chain* in **Competitive Advantage** (New York: The Free Press, 1985) and 1) presents a strategic market analysis of the hazard waste remediation industry and 2) evaluates the Corps potential roles in technological innovation for application in this industry.

MARKET SEGMENTATION

The Hazardous Waste Management industry consists of four (4) segments: 1) Laboratory Analysis, 2) Engineering, 3) Remediation, and 4) Treatment, Storage, and Disposal. In the spectrum of Corps missions, Hazardous Waste Management falls under Facilities Engineering/Management, where an engineer and his staff maintain Army installations, from energy production to trash disposal. The four (4) segments are handled, in varying degrees, both at the installation level and in engineering divisions and labs around the world. As the world's largest purchaser of construction services, the Corps plays an important role in domestic

construction. Consequently, the construction-oriented remediation segment becomes particularly important.

The products and services provided by the Corps include 1) construction management, 2) engineering and design, 3) laboratory support, 4) real estate development and management, 5) emergency operations, and 6) regulatory functions. Additionally, the Corps has various mobilization and wartime missions that support not only US military operations, but also secure and maintain the nation's infrastructure.

The customers serviced by the Corps and its fleet of contractors are 1) federal agencies, such as the Department of Defense, the Department of the Army, and the Environmental Protection Agency, 2) state governments, in cost sharing scenarios, and 3) others, usually governments of US Territories such as American Samoa. The most important of these three (3) are the federal agencies, specifically the Department of Defense, where base closures and cleanup of aging installations are now top priorities and promise to be Herculean tasks.

Construction Management, under either military or civil works funding, is provided within the dictates of the Federal Acquisition Regulation (FAR) and its Army and Corps supplements. The primary mechanism for bringing completed

construction to the customer is the fixed price contract secured through competitive, sealed bidding. All Corps construction is performed under contract (the Corps has no organic civilian construction assets.). Engineering and design is performed either by in-house engineers or through negotiated, open-end design contracts with regional and local architect-engineer (AE) firms. Laboratory services are accomplished at all of the Corps divisions and at the three (3) Corps labs, as well as by private agencies employed by contractors during construction. Real estate development and management are functions which have been developed through vertical integration along the Corps Value Chain and deal with Army or Defense Department lands. Emergency operations are also provided at the Corps divisions to assist the Federal Emergency Management Agency (FEMA) with damage assessments and emergency construction management during national emergencies and disasters (hurricanes and earthquakes). Corps regulatory functions pertain to the nation's waterways and are also performed at all Corps divisions.

With regard to Hazardous Waste Remediation, the Corps is providing construction management services for the Defense Department ($1 billion budget for 1991 under the Defense Environmental Restoration Program)[57] and the

Environmental Protection Agency under the Comprehensive Environmental Response, Compensation and Liability Act (Superfund).

Waste Remediation market trends are very promising for the short and medium term. Since 1980, government and industry have spent between $5 and $10 billion on Superfund cleanup projects alone. This represents only a fraction of the ultimate amount, which will increase directly with the number of federal regulations, toxins, and public anxieties. The General Accounting Office estimates that over 425,000 sites may eventually require cleanup;[58] there are presently 1,236 sites identified on the Superfund National Priorities List, only 54 of which have been permanently dealt with.[59]

In the long term, hazardous waste remediation will give way to more encompassing measures of waste management, where producers will try to reduce their volumes of toxic output through recycling and better housekeeping.[60] However, even with significant environmental improvements in production processes and scale economies in on-site waste treatment, the nature and track record of Superfund suggest a bright future for remediation services.

FIVE(5) COMPETITIVE FORCES

THREAT OF NEW ENTRANTS

The potential for significant financial gain makes this industry segment especially attractive. Consequently, the threat of new entrants is HIGH and will remain so for the foreseeable future. With the enormous number of potential sites and increasing estimates of cleanup costs, this threat will continue to rise with time.

BARRIERS TO ENTRY

Barriers to entry are significant in this market segment and mitigate the threat described above, but by no means eliminate it. Regulatory uncertainties, management inexperience, and lack of trained personnel (most important for smaller firms) make entry into waste remediation a difficult task.[61] Additional barriers include significant capital investments for remediation and testing equipment, risks of future litigation (probably the most noteworthy of all), inadequate or unavailable bonding, and the slow pace of the Superfund program. Economic uncertainty (recession) also looms as a real barrier for new entrants, especially smaller firms. Along with capital investment, it poses a formidable barrier to exit which firms must consider before making the corporate leap into this segment.

The remediation market is very consolidated for the construction industry, with 70% of revenues now collected by 10% of companies. The percentage of revenues for these few large firms is expected to rise in the next ten (10) years as the industry continues to consolidate and rationalize the inherent risks and potential benefits.[62] Consequently, potential entrants will be larger firms who are able to muster the financial and technical muscle to capture new contracts. A recent Corps initiative in decentralizing procurement of remediation services has yet to change this proposition. The hope is that with decentralized control over remediation contracts, the Corps can involve more small contractors and increase the number of participating firms.[63] Another possible threat might be posed by foreign firms competing on a technological "fast follower" strategy, much like Japanese firms who acquire or copy already proven methods and apply them in more efficient ways to the production process. When one also considers the significant cost of capital advantage enjoyed by Japanese firms over their American counterparts, this set of potential entrants will represent a real threat, once new technologies are developed. Finally, major construction firms not presently competing in this segment are showing greater interest and their presence is being increasingly felt. Also marshaling

their forces to penetrate the market are the waste generators (big industry) themselves.[64]

THREAT OF SUBSTITUTE PRODUCTS OR SERVICES

The threat of substitutes is LOW, primarily due to specific guidance and tolerances in the federal regulations. The threat, if there is one, is in new and different remediation technologies. However, considering the barriers to entry discussed above, the generally uncertain nature of remediation, and our federal free market economic policies, such a threat is not formidable at this time. Though many firms are researching new remediation technologies, their implementation will be guarded, at best; they will present no challenge to proven practices until economic policies change to nurture domestic technological growth.

BUYER/SUPPLIER POWER

Buyer power and supplier power are both HIGH. Buyers of Corps (and their contractors) services brandish the threat of litigation, demanding 100% quality assurances. Suppliers of remediation services run the "only show in town" at the present time and can extract significant premiums, if not monopoly rents. The Corps may be immune to some of this power, but its remediation contractors view the influence as additional uncertainty to be programmed into their risk premiums.

RIVALRY AMONG EXISTING FIRMS

Rivalry among the few large firms in this segment is HIGH, considering the expected future boom in remediation work. However, with time, this rivalry will become more widespread to include smaller, niche competitors championing new remediation technologies. Additionally, as industry experience becomes more widespread, both in the technical and business areas, rivalry will jump accordingly.

VALUE-ADDED CHAIN

LINKAGES

From its long history as the government's construction agent, the Corps enjoys significant linkages within its own Value Chain, with the construction industry, and with other industries. Solution mechanisms for the waste remediation missions assigned by our federal civilian leadership are well established.

Within the framework of the Corps' remediation mission, technology links construction operations with all other Value Chain activities and is central to the global development of this industry segment. New remediation technologies are the key to improved competition and efficiency which, in turn, impact Corps mission accomplishment. A combination of new remediation technologies and alternate procurement methods would reduce

the risks now experienced by contractors, encourage innovation during construction, and generally feed new information back into the construction system. The synergy of information sharing in this way would increase contractor proficiency and result in a better service for Corps customers. Additionally, the Corps would act as a "testing bed" for new processes and as a "farm system" of human resource development for the industry.

MARKET IMPERFECTIONS

Imperfections in the present system deal primarily with the inefficient allocation of risk between the Corps and its contractors. This springs from the traditional procurement methods currently in use and their inherent adversarial, self-serving, and litigious nature.

If technological innovation drives true progress in this market segment, then traditional procurement methods are obviously inappropriate. To encourage technological innovation, a more cooperative approach to contracting must be employed. Alternative contracting methods will better allocate risks between the contract parties and facilitate more innovative approaches to remediation projects. Biddability, constructability, and value engineering are inherent in the process, resulting in better designs, reduced delivery times, reduced costs, and improved service.

The obstacles to entry into this very important and dynamic market should not be bureaucratic or procurement based. In a risky business such as waste remediation, which is so potentially vital to the nation and our technology base, innovative management must guide the technological innovations it seeks. Alternative contracting measures cannot dispel the risks of litigation, reduce the costs of American capital, or reconcile the short-term expectations of financiers with the long-term aspirations of industry. However, they can create an environment where innovation is strategically, operationally, and economically feasible.

Appendix D: FURTHER RESEARCH REQUIRED

This appendix offers suggestions for further research in this area. Specifically, two (2) topics are presented: 1) alternative contracting mechanisms for hazardous waste remediation projects and 2) sophisticated project valuation models for use with all US Army Cops of Engineers projects.

As discussed, the US Army Corps of Engineers, in accordance with Superfund, SARA, the Defense Environmental Restoration Program (DERP), and the Installation Restoration Program (IRP), has become responsible for remediation and closure of the hundreds of severely contaminated active military installations and abandoned sites, along with bases earmarked for closure. As DoD adapts to new missions and a reduced strategic Soviet threat, environmental restoration targets have become critical.

Several issues arise which are of import to remediation efforts and, specifically, to the construction field. First, as the government's construction agent, the Corps has at its disposal several forms of contracting mechanisms, not all of which equitably allocate operational or financial risks among contract parties. Investigating how different contracting mechanisms can be utilized to perform cleanups while also reallocating risks more equitably would be of considerable value. Second, the valuation of these projects

is normally not accomplished with more sophisticated procedures, such as Valuation by Components (VC) or Option Models (Black-Scholes). Investigating the value of remediation projects with these methods would be an important step toward a better understanding of their long term, life cycle nature. Finally, justifying the Corps taking responsibility for the Superfund cleanup program from EPA would be of significant interest, specifically from a construction management and environmental optimization view.

ALTERNATIVE CONTRACTING MECHANISMS

IMPORTANCE IN ADVANCING THE FIELD.

Understanding the risk shifting capacity of the different contracting mechanisms available to the Corps would be valuable to construction finance, and to the government, in helping to develop strategies for financing, valuing, and accomplishing risky projects. Specifically, if quantified, the value of risk shifting in these instances could be programmed back into the valuation mechanism and appropriate contracting forms could be more efficiently chosen to match the risk and the parties' abilities to bear it. In the arena of technological innovation on remediation projects, the record has been poor. Principle in this is a lack of understanding, especially by Field Operating Agencies (FOAs) of the Corps, of the magnitude of risk

associated with project-specific contracting mechanisms. There is a general understanding that conventional contracting mechanisms are adversarial and self-serving, and alternative contracts can result in shorter performance periods, reduced contract costs, and improved quality. However, quantifying this and distilling it into a decision calculus for developing contracting strategies is lacking. With risk itself as a barrier to entry into this industry, especially for smaller firms championing new technologies, such an understanding is most important. Additionally, pursuing such a research topic would help to develop project Betas for environmental remediation jobs using different contract mechanisms.

ANALYTICAL FRAMEWORK AND FORMAL PLAN.

The research plan would first identify the remediation projects now being pursued by the Corps and the contracting mechanisms used on each. I think we would want to investigate why these contract forms were chosen, specifically, whether it was organizational inertia or precedent ("that's what we know and can do without thinking too much about it"), dictated by regulation or statute, and whether it was a conscious decision of the Contracting Officer. It would be important to develop a "spread" of contract types, forming a large enough representative

sample, so some comparisons could be drawn between them. However, if only a few contracts were let by the Corps or if all were of the same form, the investigation would necessarily broaden to EPA work and projects in private industry or at the state and local level. The next step would be to try and group projects by risk category and size to compare the contract dollar amounts across the several contract types. With the fixed-price/competitive bid model as our baseline or control, we could develop risk premiums for each project and, correspondingly, contract type. From this, knowing 1) the prevailing risk free rate, either nationally or regionally, 2) something about how the contractor had leveraged the project, and 3) something about the portfolio of projects of that firm, or firms similar to it, conclusions about the BETA for the specific project could be developed. This could be extrapolated back to the type of project and contract form used, establishing a base of data (Betas) for such jobs. This database could be subsequently used by the Corps to develop risk allocation strategies for remediation projects. Such a program would help Contracting Officers in developing programs for equitably allocating the environmental, financial, and operating risks of remediation jobs by assisting them in

matching the right contract form to the type of job and contractor.

SOPHISTICATED VALUATION METHODS

IMPORTANCE IN ADVANCING THE FIELD.

The procedure normally employed by the Corps in valuing construction contracts comes directly from manuals and handbooks which outline the best estimated costs for specific construction activities. Once an estimated construction cost (ECC) is developed, a percentage for profit and overhead are added, normally 15% total, and an overall project value is developed. No project-specific consideration is given to the financial values of time, money, or risk. Consequently, the value of the project to the contractor is overstated and the costs to the government understated, from a long term, life cycle perspective. At bid openings, contract award is based upon the lowest quoted bid. If the government could value projects, and bids, using VC or an Option Model, we would better understand the premiums construction contractors place on flexibility and uncertainty, along with the risks associated with specific project types.

ANALYTICAL FRAMEWORK AND FORMAL PLAN.

There are thousands of construction contracts let by the Corps each year. They range significantly in contract

amount, scope, and risk. Of these contracts, the overwhelming predominance are fixed-price/competitive bid, as already discussed. Emphasis on "cookbook valuation" loses sight of the longer term value of jobs as well as the value to contractors of leaving options open (flexibility).

A research program in this area would be directed at determining the dollar amount by which the government is overpaying, or underpaying, its contractors each year, strictly from a financial analytical point of view. Understanding that there are significant subsidies paid by the government to firms for political reasons, the analysis would hope to establish the difference between how the government values and pays for services vis a vis how more sophisticated valuation models say they should.

A number of contracts would be selected, grouped by region, risk (degree of difficulty), dollar amount, and period (year and month, so as to consider the periodic variations in construction cycles). By group, each contract, along with the bid abstract (listing the competing contractors and their bids), would be evaluated. The spread of bids on any given job would reveal a number of things, such as, the contractor's need for work at the time of bid opening, the risk associated with the quality of plans and specifications, actual constructability risk, and how

contractors view the risks of dealing with the government. Using a regression analysis technique, Contracting Officers could establish individual risk premiums by type of jobs, type of contract, and for their commands in general. This information could be used as a mechanism for future cost programming, where the government could direct resources to reducing those sources of risk, as viewed by the contractors. For the Corps' role in IRP and waste minimization, a more sophisticated approach must be investigated.

ENDNOTES

[1] Stephen Peter Rosen, **Winning the Next War: *Innovation and the Modern Military*** (Ithaca, NY: Cornell University Press, 1991), 40.

[2] Echoing the sentiments of B. R. Inman and Daniel F. Burton, Jr. in *Technology and Competitiveness: The New Policy Frontier*, **Foreign Affairs**, Spring 1990, 116-134.

[3] Paul R. Fil, Major, US Army, **An Analysis of the Department of the Army's Performance in Meeting its Obligations Regarding the Installation Restoration Program**, MMAS Thesis, Command and General Staff College, Fort Leavenworth, Kansas: 1992, 21.

[4] Massachusetts Institute of Technology, Center for Construction Research and Education, *Global Environmental Task Group,* Presentation by Professor David Marks, Dean, Department of Civil Engineering (now Department of Civil and Environmental Engineering), 22 February 1991.

[5] Ibid.

[6] Rosen, 40.

[7] MIT *Global Envirinmental Task Group,* 22 February 1991.

[8] *Low risk* in the financial sense where the consequenses of failure are less severe, to the remediation contractor and the principle responsible party (the government) when compared with a private site.

[9] Bureau of National Affairs, **Global Environmental Issues and International Business: *A Manager's Guide to Trends, Risks, and Opportunities***, by Bradford S. Gentry, principal author (Washington, DC: 1990).

[10] MIT *Global Environmental Task Group*, 22 February 1991.

[11] William L. Robertson, *To Be Environmental Engineers For The Nation*, **Strategic Working Paper** #89-3, 11 April 1989, 4.

[12] A contracting mechanism where one (1) firm is awarded both the design and construction of a project. Traditional approaches under the Federal Acquisition Regulation require competitive bidding on design and construction separately, award going to the lowest bidder. As the design firm and construction contractor are one in the same, minimal time and confusion are to be expected when transitioning from concept to execution.

[13] A contacting mechanism similar to design-build. The contractor is given specifications to attain in a craddle to grave scenario. The term *turnkey* denotes contractor lead in all contract activities until the govenement is provided the key to a completed structure for final inspection.

[14] The adequacy of design documents (plans and specifications) as a basis for construction, in this case, remediation processes. Deals primarily with the *accuracy* of design documents.

[15] The adequacy of design documents (plans and specifications) as a basis for contractor bids. Deals primarily with the *precision* (reproducable accuracy) of design documents. High precision means less chance of cost and time overruns, especially critical in high risk contracts such as waste remediation. Consequently, such precision is crucial if small firms or innovating contractors are to secure the bonding required.

[16] Massachusetts Institute of Technology, Center for Construction Research and Education, *Global Environmental Task Group*, Presentation by Professor John Ehrenfeld, 15 March 1991.

[17] Ibid.

[18] Ibid.

[19] This point is presented to highlight that technological innovation is not the only method for improved remediation results, that is, there is no simple *technology fix* for this most complicated and tenuous problem.

[20] Rosen, 20.

[21] US General Accounting Office, report to Congressional Requesters, **Hazardous Waste: DoD Efforts to Reduce Waste**, GAO/NSIAD-89-35, February 1989, 2. Also, Michael Renner, in *Assessing the Military's War on the Environment*, **State of the World 1991: A Worldwatch Institute Report on Progress Toward a Sustainable Society**, 143.

[22] Lenny Seigel, Gary Cohen, and Ben Goldman, **The U. S. Military's Toxic Legacy: *America's WorstEnvironmental Enemy***, The National Toxics Campaign Fund (January 1991), 1-2.

[23] The original National Toxics Campaign estimate (January 1991) quoted a total of 14,401 "potentially contaminated" sites identified by the Defense Department. Since that time, DoD has increased the number in an annual report to Congress to more than 17,000. These sites range from entire firing complexes and production facilities to locations where only a few barrels of contaminants require disposal. (Source: Contamination report, **Army** vol 41 no 5 (May 1991), 64).

[24] Siegel, et al, 3-4.

[25] Ibid., 11.

[26] Ibid., 3.

[27] Ibid., 1.

[28] My personal experience in researching this topic led to a closed door at the Huntsville Engineer Division. When I inquired about overall program goals and results, a well as specific project information, I was routed to the Public Affairs Office for a prepared statement. Specific information was denied me for *national security reasons.*

[29] *Compartment* refers to one (1) of six (6) parts of the environment within which toxics and contaminants migrate and eventually contact humans. These compartments are 1) air, 2) water, 3) land, 4) suspended solids in water, 5) bottom sediment in water, and 6) biota. Understanding how military contaminants migrate between and within compartments, based on chemical mass balances, will help describe the dynamic and pervasive nature of the environmental problems that may arise.

[30] Siegel, et al. This report is replete with specific examples where military toxics have migrated off the installation and contaminated civilian communities. See pages 12, 14, 17, 28, 34, 43, 48, 57, 60, 75, and 80.

[31] Ibid., 24.

[32] The specifics of this program are found in the **US Army Installation Restoration Program Guidance and Procedure (December 1990)** prepared by the US Army Corps of Engineers Toxic and Hazardous Materials Agency at Aberdeen Proving Groundsm MD.

[33] Siegel, et al, 25-26.

[34] The federal government cannot be sued by individuals nor states. Consequently, DoD installations are immune from prosecution.

[35] DoD and EPA are both agents of the executive branch of our government. The executive unity theory holds that the executive branch cannot sue itself, as the Justic Department works for both DoD and EPA. Combined with the principle of sovereign immunity, the federal governemnt is immune to prosecution from *without* and *within.*

[36] Siegel, et al, 38.

[37] Rosen, 60.

[38] Ibid., 64.

[39] Ronald C. Sims, *Soil Remediation Techniques at Uncontrolled Hazardous Waste Sites: A Critical Review,* **Journal of the Air Waste Management Association,** vol 40 no 5 (May 1990): 706.

[40] Environmental Protection Agency, Office of Environmental Engineering and Technology Demonstration, **Guide to Treatment Technologies for Hazardous Wastes at Superfund Sites,** EPA/540/2-89/052 (Washington, D. C.: March 1989), 1.

[41] Ibid., 8.

[42] Ibid., 11.

[43] Ibid., 16.

[44] Ibid., 17.

[45] Sims, 706.

[46] EPA/540/2-89/052: March 1989, 1.

[47] Lawrence Susskind and Michael Elliot, *Learning from Citizen participation and Citizen Participation in Western Europe*, **The Journal of Applied Behavioral Science** vol 17 no 4 (1981): 500.

[48] Robertson, 4.

[49] Ibid., 3.

[50] Rosen, 52.

[51] Unless otherwise noted, all definitions are from Fil, 1991, MMAS, 117.

[52] Rosen, 7.

[53] Ibid., 7.

[54] Ibid., 40.

[55] Sybil P. Parker, ed., **McGraw-Hill Concise Encyclopedia of Science and Technology** (New York: McGraw-Hill Book Company, 1984), s.v. *Technology*, by Harold B. Maynard and Robert S. Sherwood.

[56] Fil, 113.

[57] __________, *DOD Reveals Cleanup Details*, **Engineer News Record**, 26 November 1990, 10.

[58] Debra K. Rubin, *Cleanup Dollars Flow Like Water But Industry Awash In Problems*, **Engineer News Record**, 9 March 1989, 30.

[59] __________, *Superfund Is Making Strides, But It Still Has A Dark Side*, **Engineer News Record**, 26 November 1990, 128.

[60] David A. Hanson, *Hazardous Waste Management: Planning To Avoid Future Problems*, **C&EN**, 31 July 1989, 14.

[61] Rubin, 30.

[62] Hanson, 17.

[63] *DOD Reveals Cleanup Details*, 10.

[64] Rubin, 36.

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